Nuclear Targets for FGT

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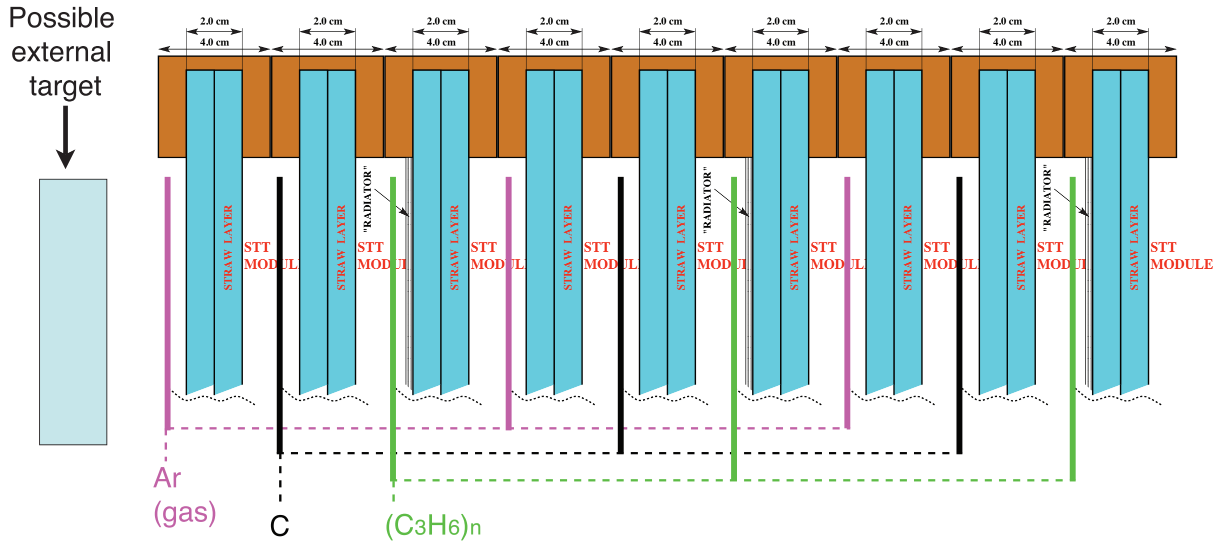
DUNE ND Working Group Meeting
September 24, 2015

NUCLEAR TARGETS

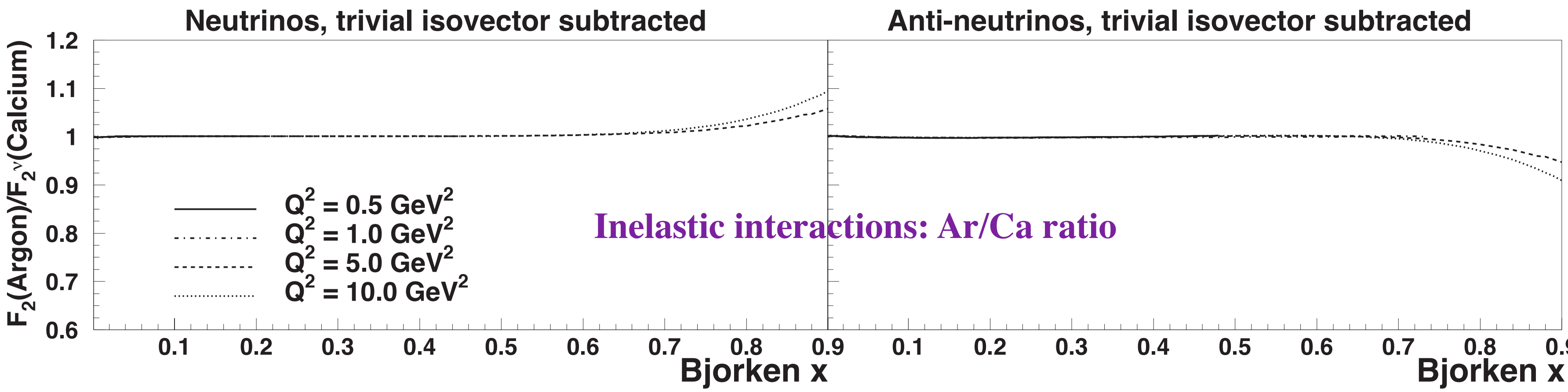


MAIN target
$(C_3H_6)_n$ radiators:
mass $\sim 5t$

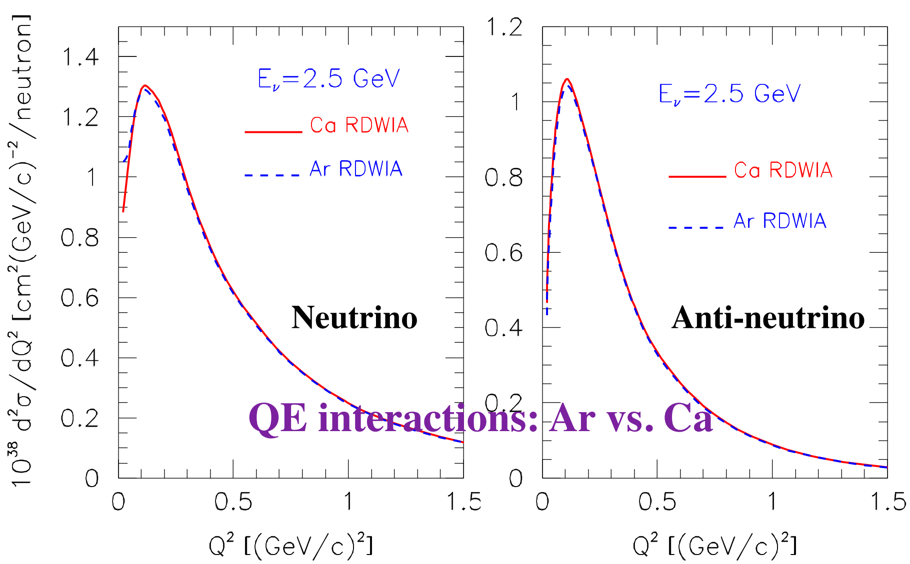
- *Multiple nuclear targets in STT: $(C_3H_6)_n$ radiators, C, Ar gas, Ca, Fe, H_2O, D_2O, etc.*
  $\Longrightarrow$ *Separation from excellent vertex ($\sim 100\mu m$) and angular (< 2 mrad) resolutions*

- *Subtraction of* $\boxed{\text{C TARGET}}$ *(0.5 tons) from polypropylene* $\boxed{(C_3H_6)_n \text{ RADIATORS}}$ *provides* $5.0(1.5) \times 10^6 \pm 13(6.6) \times 10^3 (sub.)$ $\nu(\bar{\nu})$ *CC interactions on free proton*
  $\Longrightarrow$ *Absolute $\bar{\nu}_\mu$ flux from QE*
  $\Longrightarrow$ *Model-independent measurement of nuclear effects and FSI from RATIOS A/H*

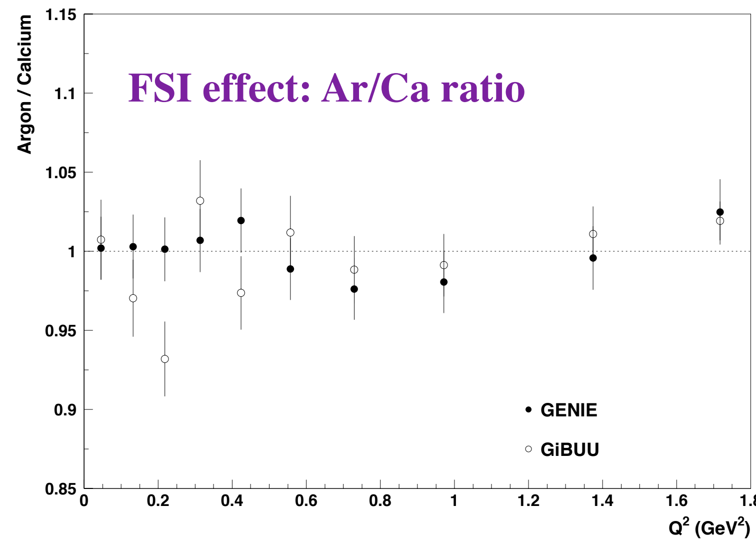
- *Pressurized* $\boxed{\text{Ar GAS}}$ *target ($\sim$ 140 atm) inside SS/C tubes and solid* $\boxed{\text{Ca TARGET}}$ *(more compact & effective) provide detailed understanding of the FD $A = 40$ target*
  $\Longrightarrow$ *Collect $\times 10$ unoscillated FD statistics on Ar target*
  $\Longrightarrow$ *Study of flavor dependence & isospin physics*



S. Kulagin and R.P, NPA 765 (2006) 126-187; PRD 76 (2007) 094023
PRC 82 (2010) 054614; arXiv:1405.2529 [hep-ph]



A.V. Butkevich, PRC 85 (2012) 065501; A.V. Butkevich and S. Kulagin, PRC 76 (2007) 045502



HRI Group, GENIE and GiBUU simulations

LONGITUDINAL PROFILE OF STT

- *Reference configuration of STT planes (from downstream to upstream):*
  - *Total of 75 STT XXYY modules with 4 straw layers and integrated radiators*
    $\Longrightarrow$ *Overall length of 600 cm* $\longrightarrow \sim 1.09X_0$ *and mass* $\sim$ *5.18 tons*
  - *Total of 2 STT XXYY modules with radiators replaced by graphite targets (total 18 mm C)*
    $\Longrightarrow$ *Overall length 16 cm* $\longrightarrow \sim 0.093X_0$ *(*$\rho = 1.74$ *g/cm*^{3}*,* $X_0 = 19.41$ *cm) and C mass* $\sim$ *384 kg*
  - *One plane with 7 mm thick Ca target with C-fiber/composite enclosure, followed by one STT XXYY module without radiators*
    $\Longrightarrow$ *Overall length 8 cm* $\longrightarrow \sim 0.067X_0$ *(*$\rho = 1.54$ *g/cm*^{3}*,* $X_0 = 10.41$ *cm) and mass 132 kg*
  - *One plane with 68 2-in inner diameter (0.04-in wall) C-composite tubes (some R&D needed) filled with pressurized Ar gas at 140 atm, followed by one STT XXYY module without radiators*
    $\Longrightarrow$ *Overall length 12 cm* $\longrightarrow \sim 0.02X_0$ *and Ar (C) mass* $\sim$ *112 (66) kg*
  - *One plane with 1 mm steel (Fe) target followed by one STT XXYY module without radiators*
    $\Longrightarrow$ *Overall length 8 cm* $\longrightarrow \sim 0.057X_0$ *(*$\rho = 7.874$ *g/cm*^{3}*,* $X_0 = 1.76$ *cm) and mass 96.5 kg*

  $\Longrightarrow$ *Total longitudinal STT length 644 cm equivalent to* $\sim$ *1.3* X_0 *and* $\sim$ *7.1 tons*

- *Need to optimize the design and integrate Ar, Ca, C targets with the STT modules*

- *Need to develop mechanical engineering model for the Ar, Ca, C targets*

RADIATOR TARGETS

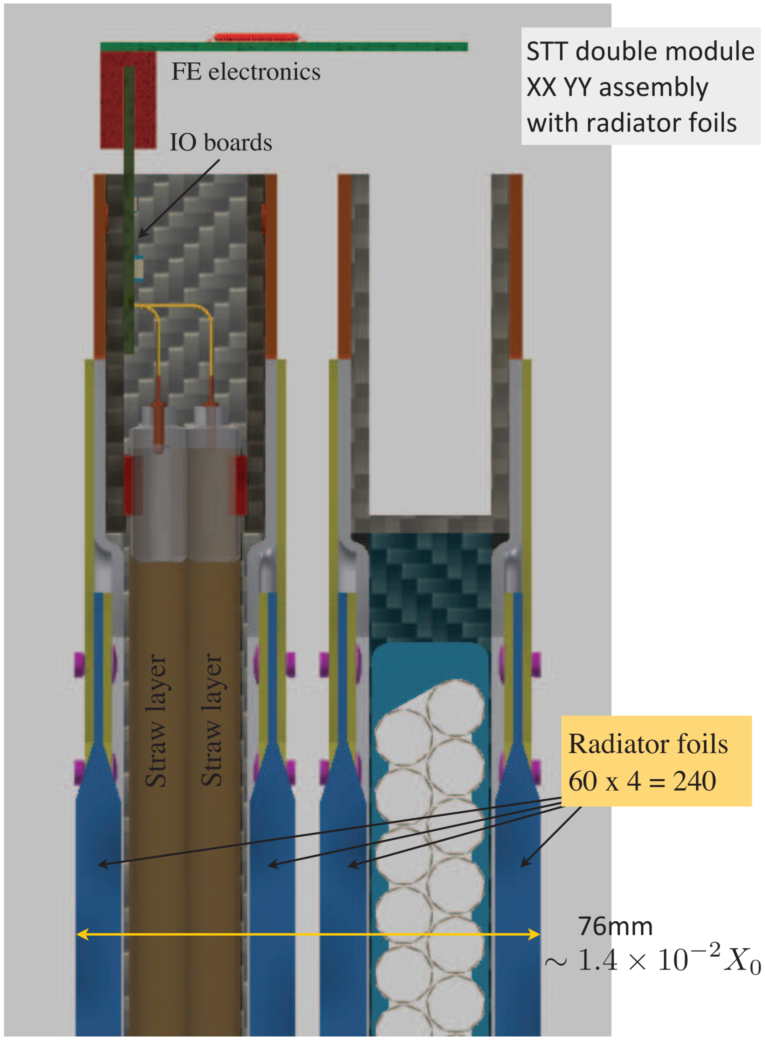
- *Design and physics performance (Transition Radiation) of radiator targets optimized (docdb # 9766)*

  $\Longrightarrow$ *Mechanical engineering model available*

- *Radiator targets integrated at both sides of each STT (double layer) module to minimize overall thickness (foils could be removed if needed):*
  - *Embossed polypropylene foils*, *25 μm thick, 125 μm gaps;*
  - *Total number of radiator foils 240 per XXYY module*, *arranged into 4 radiators composed of 60 foils each;*
  - *Total radiator mass in each XXYY module: 69.1 kg, $1.25 \times 10^{-2} X_0$.*

  $\Longrightarrow$ *The radiator represents 82.6% of the total mass of each STT module*

  $\Longrightarrow$ *Tunable for desired statistics & p resolution*



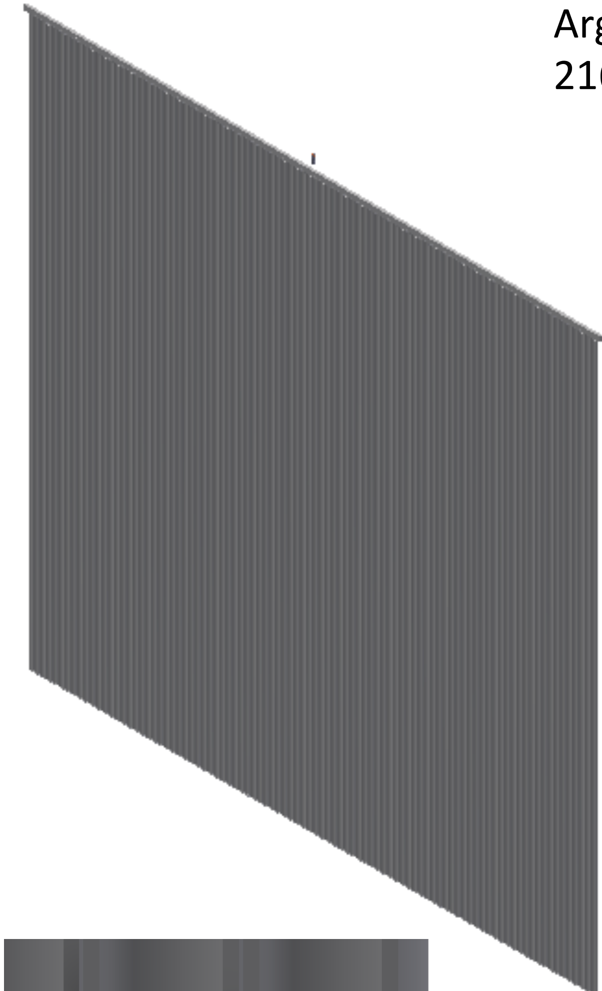
ARGON TARGET

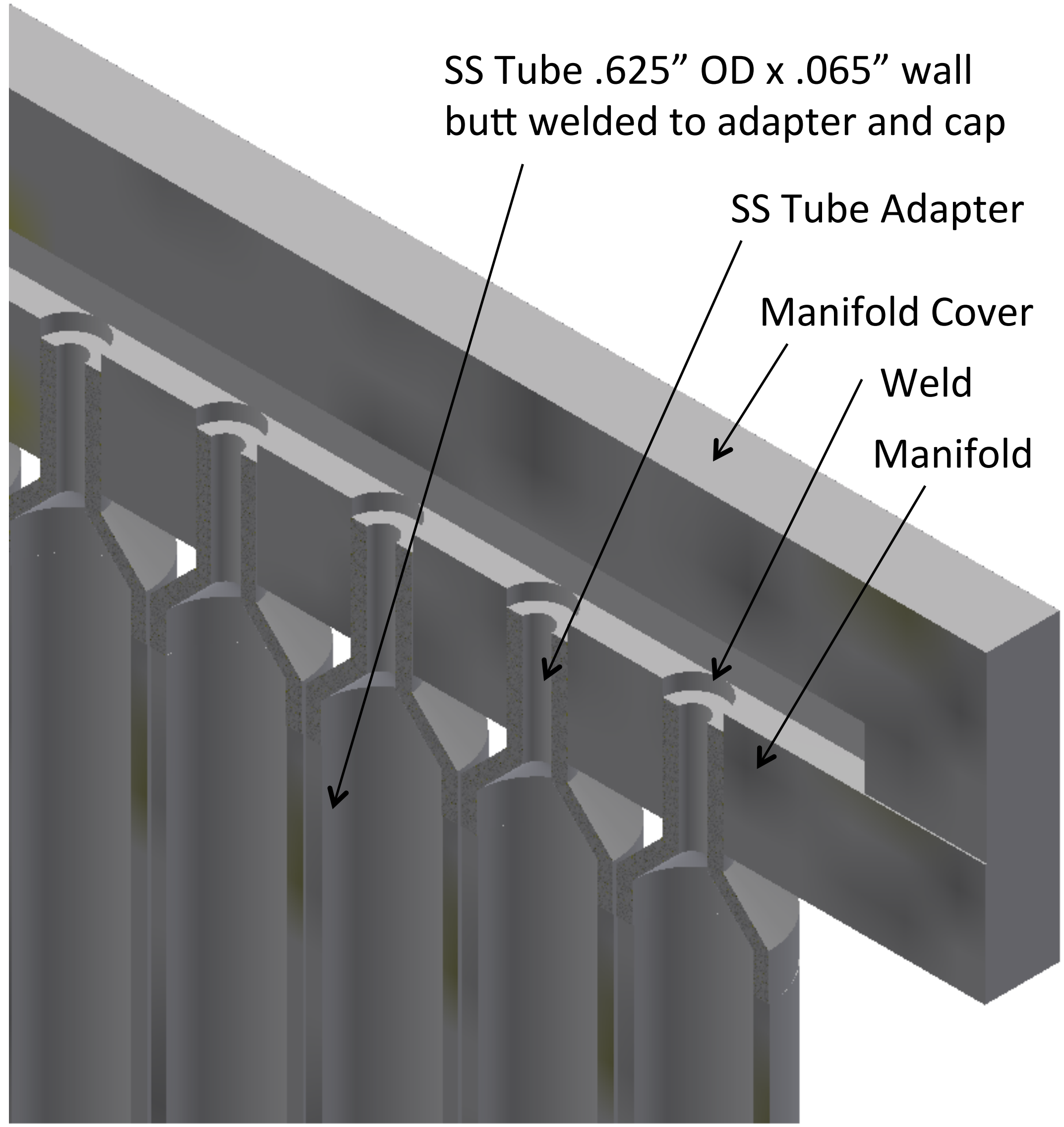
✦ *Design constraints for the Ar target:*

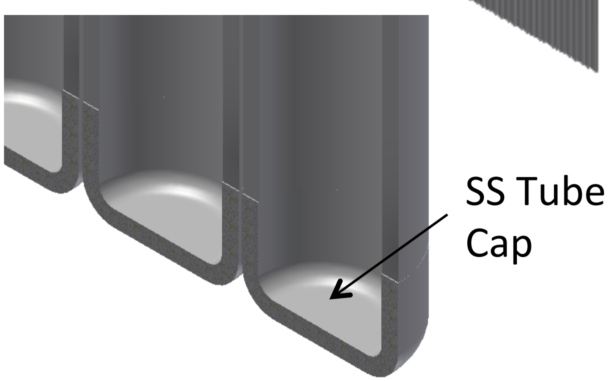
- *A FD LAr mass of 40 kt corresponds to a ND mass of 7.8 kg after scaling for the distance*
- *The fiducial volume cut (3m $\times$ 3m) has efficiency 73%*
  $\Longrightarrow$ *Need an Ar mass > 107 kg in FGT to collect 10 times the statistics in the Far Detector*
- *Use pressurized Ar gas at 140 atm ($\rho = 0.233$ g/cm^3) or higher inside cylindrical tubes followed by one XXYY STT module without radiators*
- *Need to use C-composite tubes (up to 500 KSI) to minimize enclosure material and provide higher strength than steel (welding $\sim$ 10 KSI)*
  $\Longrightarrow$ *Proof of concept with stainless steel tubes 0.5-in diameter, walls 0.065-in thick*
  $\Longrightarrow$ *Use a single plane of C-composite tubes of larger diameter to optimize the Ar/C mass*
- *Keep a safety factor > 4 for the Hoop / longitudinal stress in the design*
- *Better to consider pre-filled and sealed Ar tubes (with safety valve) to avoid complex manifolds (risk of failure, weldings, etc.)*

✦ *Need to validate the design of C-composite tubes for pressurized Ar by building and testing small scale prototypes*

Argon Gas Target Assembly – SS Version
216 tube assemblies welded to manifold







CALCIUM AND CARBON TARGETS

✦ *Design constraints for the calcium (Ca) target*

- *Calcium target needs to be enclosed in a C-fiber/composite and possibly oil-coated for safety (protect from moisture etc.)*
- *Single plane of Ca ($\rho = 1.54$ g/cm^3, $X_0 = 10.41$ cm) 7 mm thick to minimize effect of enclosure followed by a STT XXYY module without radiators*
  $\Longrightarrow$ *Total Ca mass must be comparable to the total pressurized Ar mass*
- *Can split the Ca plane into an array of smaller sub-panels*

✦ *Design constraints for the C (graphite) target*

- *Graphite slabs to be integrated into the mechanical structure of the STT modules*
- *Can replace radiators by thin C (graphite) planes in STT XXYY modules (4 straw layers) ($\rho = 1.74$ g/cm^3, $X_0 = 19.41$ cm)*
  $\Longrightarrow$ *Need total mass of C target $\sim$ 400 kg while keeping overall thickness $<$ 0.1 X_0*

✦ *Need to validate the design of Ca, C and radiator targets by building and testing small scale prototypes*

Backup slides

TRANSITION RADIATION

- *Simulation of Transition Radiation (TR) based on formalism by Garibian (1972), Cherry (1975)*
  $\Longrightarrow$ *Narrow energy range $\sim$ few keV*

- *Radiator design optimized for TR performance:*
  - *TR build-up over many interfaces;*
  - *Self-absorption of lower part of energy spectrum;*
  - *Need compact radirors to keep large tracking sampling.*

  $\Longrightarrow$ *Select 25 μm foils, 125 μm spacing*

- *On average 1.1 TR photons with $E > 5$ keV detected in a single STT module from a 1 GeV e*

- *dE/dx in straws are of the same order as TR at energies of few GeV: a 5 GeV e(π) has a probability $\sim 41\%(18\%)$ of depositing $E > 6$ keV*